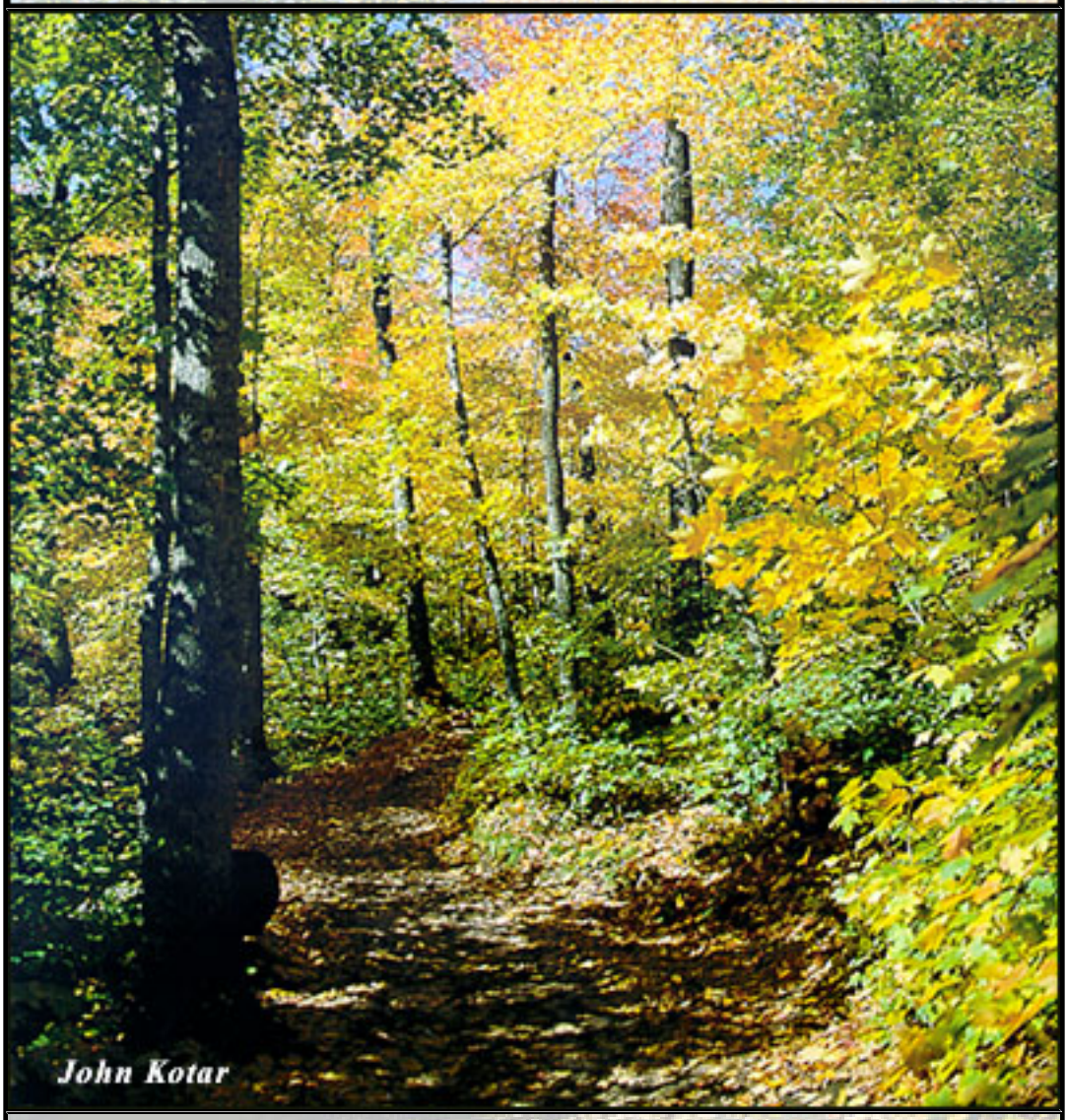
Approaches to Ecologically Based Forest Management *On Private Lands*



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Introduction

The management philosophy advocated by many public agencies today has become known as "ecosystem management." Under this philosophy, maintenance of ecosystem structure and functions becomes the primary goal, while production of commodities and services is viewed as a useful byproduct. However, any effort to assure sustainability and health of American forests can be expected to succeed only if private ownerships, which comprise the majority of forest land, are included. Following this reasoning, it becomes immediately obvious that for realistic application of ecological principles to forest management on private ownerships, the owners' goals and management objectives must be kept in the forefront. They cannot become secondary concerns.

This publication is aimed at natural resource professionals who prepare forest management plans for private landowners. However, the ecological concepts presented apply to all ownerships.

The goal of the publication is twofold: 1) to review some ecological principles that are reasonably well understood and that can be applied to forest management; and 2) to suggest a method for identifying a range of management alternatives by considering ecological principles, as well as landowners' goals, constraints and opportunities.

It is our hope that heightened knowledge of forest resources and ecological forces at work, together with landowner involvement, will increase the success of forest-planning efforts.

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PART I: Ecological concepts upon which forest management is based

Although trees are sometimes viewed as a crop, a forest is more than a collection of trees and bears little resemblance to agricultural plantings. In order to manage forests, a resource professional must try to understand them as functioning ecosystems.

Working Definition of Ecosystem

Ecosystems are comprised of all living and nonliving components that interact on a particular segment of a landscape. For research or management purposes, boundaries between different terrestrial ecosystems can arbitrarily be established, but absolute or "natural" boundaries between adjacent ecosystems cannot be objectively defined. No one can claim sufficient functional understanding of even the simplest of ecosystems to the degree necessary to manipulate them with fully predictable results. Thus, what is called "ecosystem management" is more of an approach to management rather than a cause and-effect method of control, which is the more common meaning of the term "management."

The goal of forest ecosystem management is to develop methods of extracting human commodities and amenities from forest ecosystems in ways that do not greatly alter the processes that shape the development of natural forest communities. We are not attempting to control ecosystem processes directly, since we do not fully understand them. Rather, we wish to alter them as little as possible. Considering the limits of our current knowledge, I believe this approach is the best way to assure sustainability of those ecosystem outputs upon which societies, as well as individual landowners, depend.

Structure and Composition of "Natural" and Managed Forests

"Natural" or native forests are assemblages of regional plant and animal species able to coexist in a particular environment. This composition is in a constant state of flux as individual populations react to changes in their immediate environments brought about by internal and external forces. Natural forests can be simple or complex in terms of species composition and arrangement of age classes (structure), depending on their developmental stage and on a site's physical limitations. Many ecologists now agree that on a landscape scale, and over long periods of time, naturally developed forest communities result in the greatest amount of biological diversity possible under the prevailing climatic and soil conditions in a given region.

Managed forests are manipulated to produce specific commodities or benefits. Traditionally, wood production and consumptive wildlife have been the dominant commodities. Managed forests are generally less complex than natural forests because management typically attempts to optimize only a few species - usually those of high commercial value; those which are characterized by fast growth (high productivity); or those that can be grown in pure stands or in relatively simple mixtures. Economic considerations often lead to additional structural and compositional limitations, such as rotation age, maximum diameter, fixed spacing and elimination of competing vegetation.

The simplified composition and structure of managed forests reduce the number of possible niches in a forest ecosystem, resulting in lower regional biodiversity than might otherwise be possible. However,

there is as yet no convincing scientific evidence that such simplified managed communities necessarily lose long-term productivity, resiliency or health. A consensus is emerging among scientists that the concepts of forest health and forest productivity can be framed only in the context of management goals and objectives.

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Forest Dynamics

Every forest is in a state of change at all times. This change is not always apparent through direct observation even to a trained forester. Most foresters simply do not have the opportunity to work in the same forest for more than a decade - too short a time, in most cases, to directly observe changes in composition and structure. Nevertheless, forest managers must understand the factors and conditions that control such changes if they are to achieve the desired management outcomes. *Understanding natural forest dynamics in a particular region should be the foundation of every management action.*

Silviculture, by definition, involves planned change. If we do not understand the natural dynamics, we cannot effect a planned change. Too often, foresters assume that an existing, desirable forest cover type can be maintained by the same silvicultural treatment that was successful in another area or on another site. This, of course, may not be so if the two stands exist on significantly different site types or have resulted from different disturbances. Examples of such cases are probably known to every forester. Thus, a forester should not begin with the unqualified assumption that maintenance of the current cover type should automatically be the future management objective. Often, conversion to some other composition or structure, by taking advantage of natural trends, may meet or exceed management expectations and simultaneously improve ecological conditions.

Although every geographic region is unique in terms of its forest composition and the role each species plays in forest dynamics, some general models of forest change can be discussed. When speaking of forest dynamics, we usually envision some model of shade tolerant species replacing a less tolerant one. However, this classic model of succession represents only one of many modes of forest change. Some of the better understood modes of change are described below.

Compositional change through "relay floristics" (the classic successional model)

Often, when a forest is severely disturbed by natural forces or by complete removal of trees through logging, the "new" forest is composed of different species compared to the "original" forest. These "pioneer," or early successional, species making up the "new" forest are generally (but not always) intolerant of shade and will not reproduce in the understory to form another generation. Only another disturbance or silvicultural intervention can re-initiate this stage. Without such a disturbance or intervention, other more shade-tolerant species gradually replace the pioneer forest. Depending on the region, this replacement may occur through two or more stages. Ecologists refer to this type of succession as "relay floristics" (Figure 1). The course of this type of succession is also strongly affected by site type and other factors to be discussed in subsequent sections.

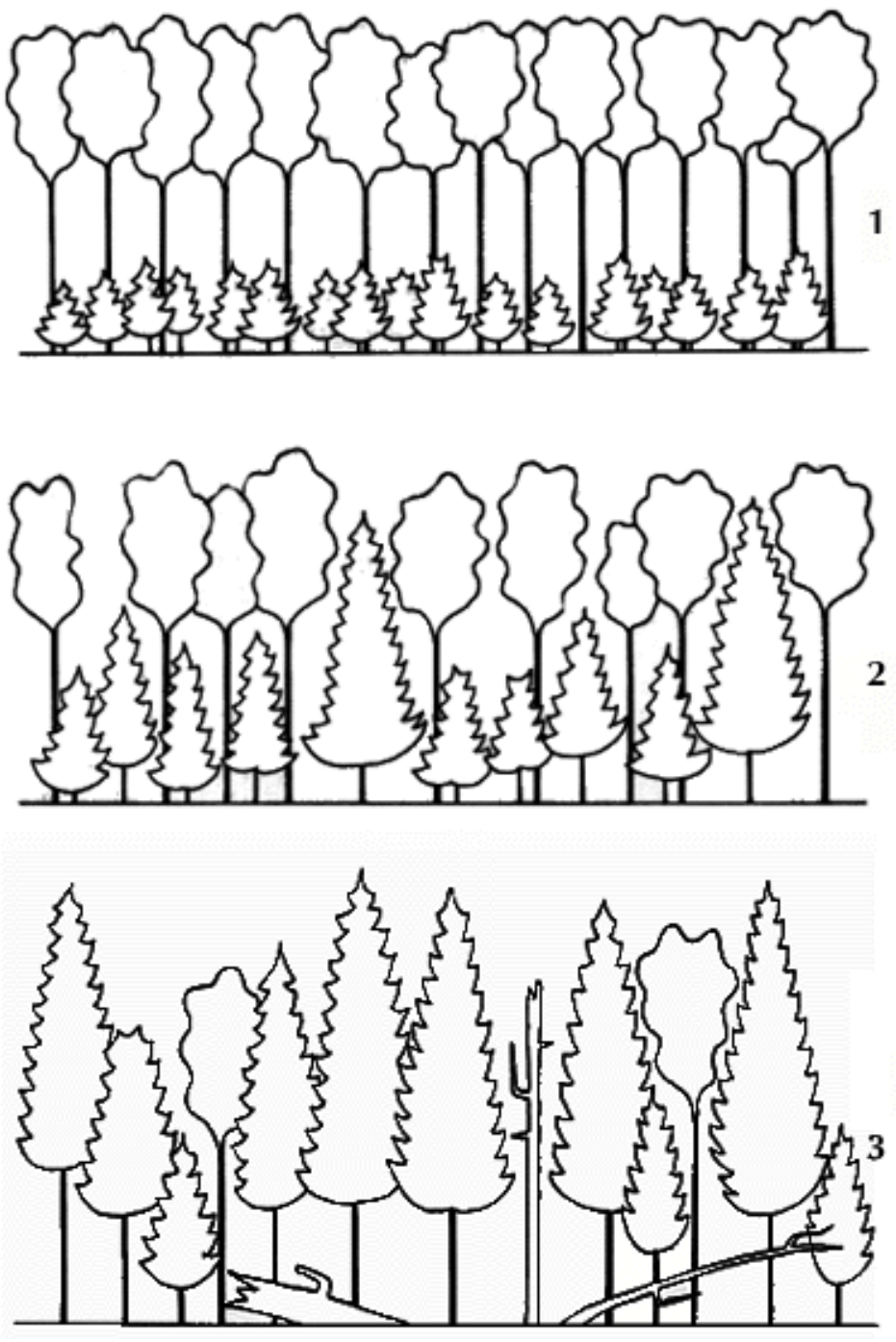

Figure 1. An example of "relay floristics" type of succession. In this case, balsam fir is replacing trembling aspen.

Change through "gap replacement"

In many cases, forest composition does not change so completely or in a singular direction as it does in the case of the relay floristics model described above. Many tree species are moderately tolerant of understory conditions, particularly in juvenile stages, and persist in a stand for some time. These species are able to take advantage of openings in the canopy that occur through either small-scale disturbances or death and removal of both individual and small groups of trees. This mode of replacement is strongly dependent on the composition of the stand and site type.

Oak seedling taking advantage of a canopy gap.

For example, if a stand is a mixture of midtolerant (e.g., red oak - white ash) and tolerant (e.g., sugar maple) species, and occurs on a rich mesic site, any canopy gaps that occur through death of single trees are likely to be "captured" by tolerant species. This is because tolerant species are likely to be better represented in the reproduction layer and their growth rates are optimal on such sites. On the other hand, if a similar stand develops on a drier, less fertile site, the mid-tolerant species have a greater chance to fill gaps because on these sites their growth rates exceed those of the more moisture- and nutrient-demanding tolerant species.

This situation is depicted in Figure 2. Stage 1 in Figure 2 represents a sugar maple-dominated stand with occasional white ash and red oak mixed in. The reproduction layer is likewise dominated by sugar maple, but a few white ash and red oak seedlings can be found. Stage 2 shows a canopy gap where a mature tree died. The seedlings that are taking advantage of this gap are those of faster-growing white ash and not the more ubiquitous, but slower-growing sugar maple. The gap was not large enough to also accommodate a red oak seedling at the edge of the gap. Stage 3 shows the original gap filled by two white ash trees and the formation of another gap. This time, no white ash or red oak seedlings were present in the location of the gap, and the space was filled by sugar maple saplings. The white ash and red oak seedlings still shown in the understory of stage 3 will not survive the suppression. In the absence of major disturbance in this type of stand, continuous gap replacement maintains a mixed composition and multi-aged structure.

Changes through gradual stand development following a stand-replacing disturbance

The so-called climax, or late successional, forest communities are thought to be self-replacing due to the ability of canopy species to form advance regeneration. However, such advance regeneration is not continuously present in many types of climax communities, or if present, it is not continuously advancing into the canopy layer. Instead, such communities are transformed through a series of recognizable stages: stand initiation, stem exclusion, understory reinitiation and old, multi-aged community (Figure 3):

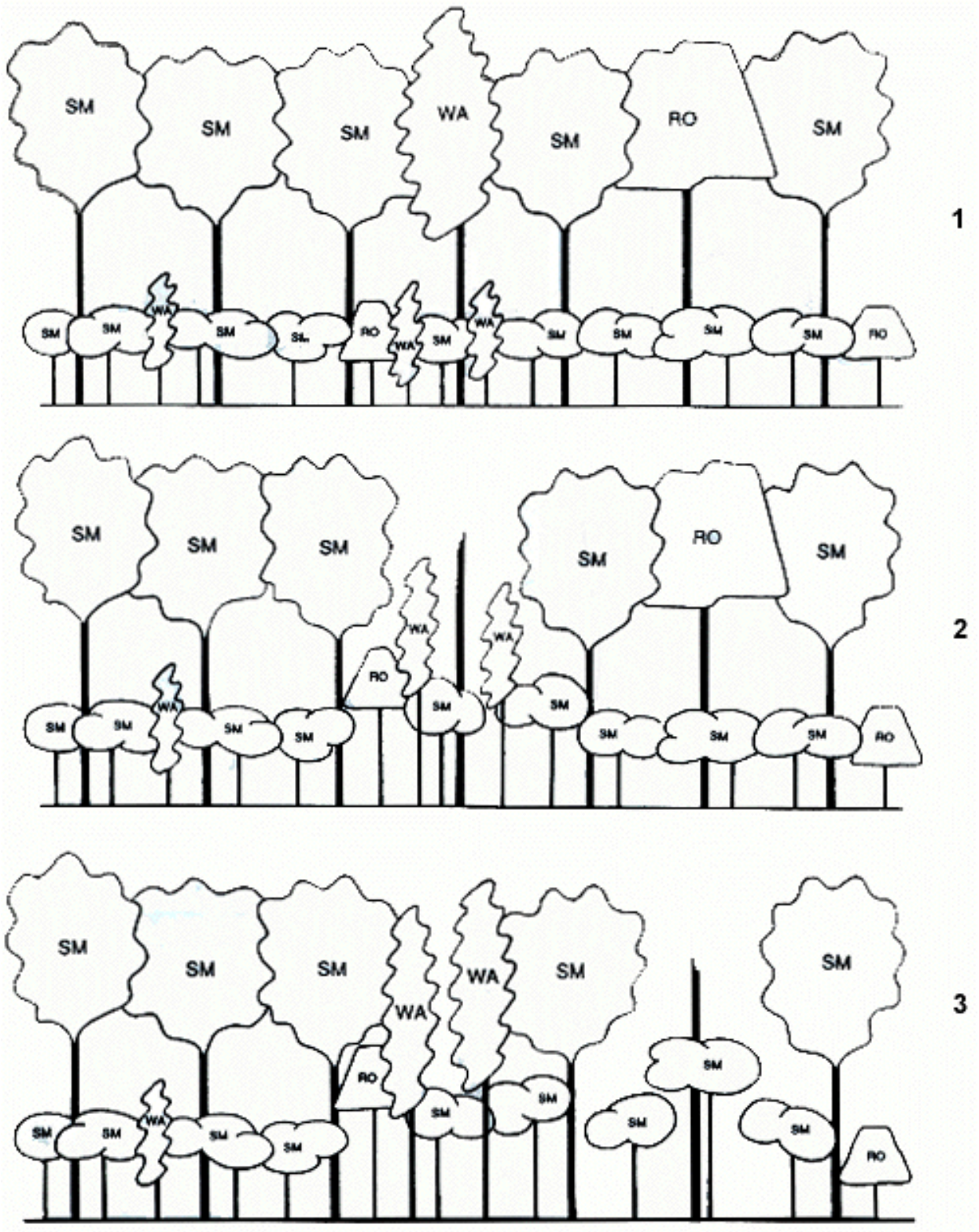

Figure 2. Canopy gap replacement as a function of chance occurrence of seedlings in the gap area and differential growth rate of species on a dry-mesic site.

SM=sugar maple
WA=white ash
RO=red oak

See text for further explanation.

Stage 1. Stand initiation. This follows major disturbances, such as catastrophic wind, fire or clearcutting.

The open space becomes filled with individuals that arrive by seed (e.g., paper birch, yellow poplar, aspen, cherry), stump sprouts (e.g., oak after fire) and root sprouts (e.g., aspen after clearcutting), or that were present as advance regeneration (e. g., sugar maple or other shade-tolerant species after a tornado or logging removes the canopy).

Aspen root suckers.

The individuals are part of an age group called a cohort. This stage ends when the canopy becomes continuous and trees begin competing with each other for light and canopy space.

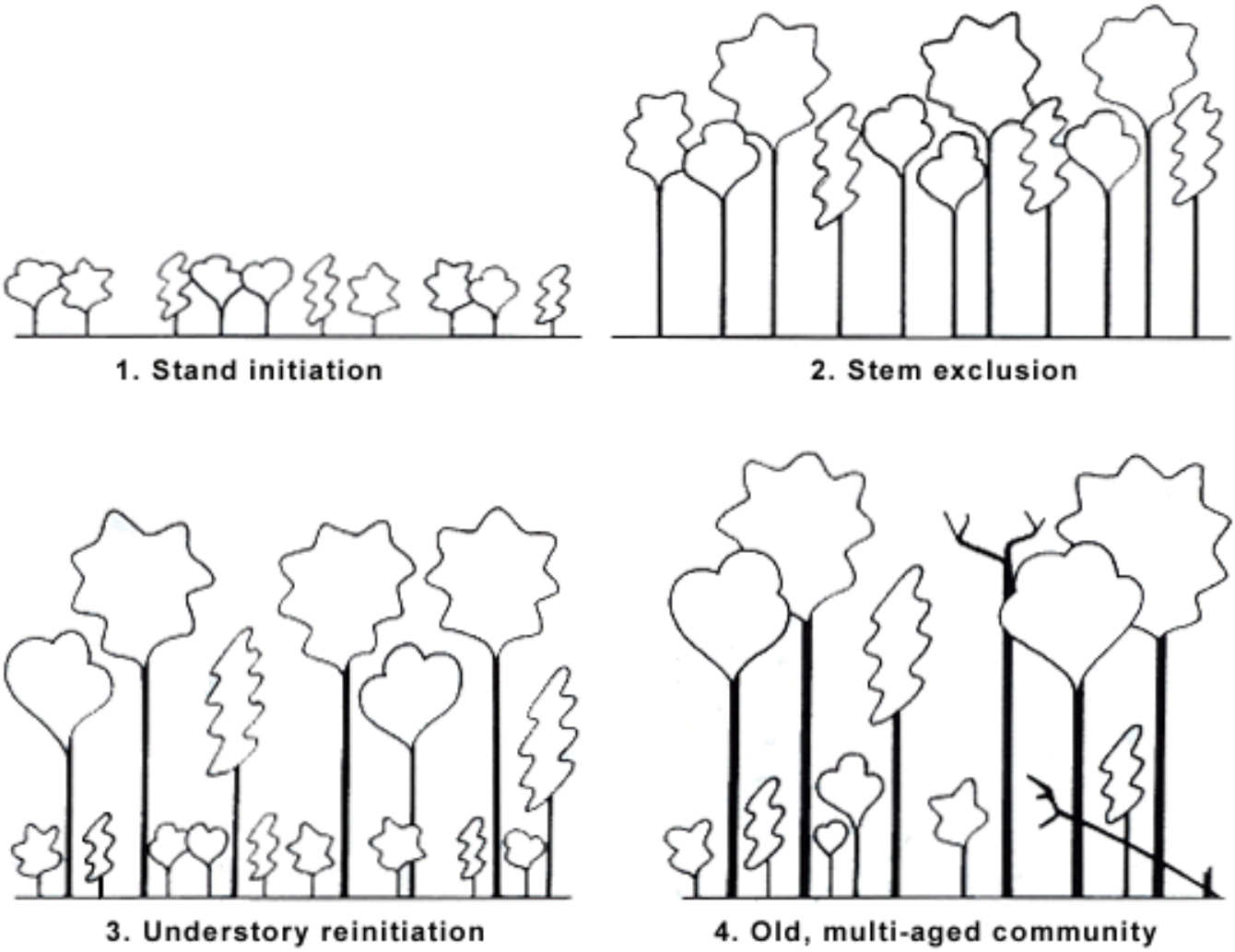

Figure 3. Changes in stand structure without species replacement. See text for explanation.

Stage 2. Stem exclusion.
During this stage, the canopy is dense enough to prevent new saplings from growing into the canopy - there is no space available for new canopy trees.

The canopy continues to have only one dominant cohort, with a relatively smooth upper canopy surface. Competition among trees is intense and density-dependent self-thinning is the major cause of mortality.

Crowns are small enough so that when one tree dies, the other trees are able to fill the vacated space in the canopy by expanding their crowns. The duration of this stage varies with species and geographic region. For example, in the Lake States and the Northeast, this situation continues for 75-150 years in northern hardwoods and red or white pine stands, but may last only 20 to 40 years in some aspen and jack pine stands.

Stage 3. Understory reinitiation.
At this point, a stand undergoes demographic transition from one cohort to more than one cohort. There may be a wave of high mortality as many trees reach old age at the same time. The crowns of the trees are now large enough so that when one dies, the surrounding trees cannot fill the gap. As a result, a new cohort of trees has space to enter the canopy. The diameter distribution becomes a compound of the two cohorts - an old unimodal peak in larger size classes and a new peak in the small size classes.

If the stand was originally composed of a pioneer species (e.g., paper birch, aspen or yellow poplar), shade-tolerant trees such as sugar maple or beech may begin entering the canopy. If there are more gaps in the canopy and more light on the forest floor, some of the mid-tolerant trees, such as white ash, red maple, yellow birch and white pine, also may enter the canopy. Mortality undergoes a transition from mostly density-dependent self-thinning to mostly density independent mechanisms, such as senescence, windthrow (due to weakened wood caused by heartrot) or disease. The stand begins to take on "old growth" characteristics, with large rotten logs on the forest floor, many tree sizes and an uneven canopy surface.

Stage 4. Old, multi-aged community.
At this point, demographic transition is complete; the forest has many age classes and size classes of trees in the canopy. There may be few or no remnants left from the original cohort. Mortality is continuous at a relatively low level, with death occurring mainly in individuals or small groups of trees.

In the Eastern Deciduous forest region, this model of forest regeneration may also apply to communities of mid-tolerant species where seed sources of shade-tolerant species do not exist.

This situation is most common in the so-called Oak-hickory region where potential shade-tolerant, climax dominants such as sugar maple, American beech and perhaps basswood, are believed to have been eliminated from much of the landscape by wild- and human-caused fires in the pre-European settlement period. Under these conditions, mixed oakhickory forests developed because oaks and hickories have a strong ability to sprout when tops are killed by fire. Today, however, when wildfires no longer control understory competition, these forests have almost no oak regeneration. This is especially so on the most productive mesic sites. Instead, oak-dominated forests tend to be replaced by species of moderate shade tolerance, such as red maple, red elm, boxelder or shagbark hickory. In the absence of management, this type of forest tends to follow the cycle described above: stem exclusion, to understory reinitiation, to old, multiaged community.

Other factors influencing change in composition and structure

Composition of original stand
Stand composition prior to disturbance or silvicultural manipulation has a strong influence on the direction and rate of change. Some ecologists refer to this effect as "biological legacy." The most obvious influences are factors such as the abundance and composition of advance reproduction, the ability of member tree species to sprout and seed availability, but other variables are also

Fire of stand replacing intensity.

Aftermath of a stand-replacing fire.

Windthrow.

important. These include the condition of the forest floor itself (e.g., exposed mineral soil, type of humus, moss) and the presence of a vigorous herbaceous or shrub layer that may compete with tree seedlings. Also important may be population levels of various herbivores, including seed predators, as well as soil microorganisms, both pathogenic and beneficial.

Seed source availabilityAvailability of seed is an obvious requisite for any compositional change. In most forests, species composing the existing stand supply the vast majority of seed that reaches the forest floor. However, seed presence on the forest floor does not necessarily guarantee species' success in an germination and survival. Oak stands, especially on mesic sites, are good examples of such a condition. Often wind- and bird-disseminated seeds from sources outside of the stand comprise the majority of successful reproduction. Because availability of such external seed sources can be observed only on a case-by-case basis, no general predictions of successional change in any given forest cover type can be made. Thus, all generalized successional models are predicated on seed source availability.

Disturbance

Compositional and structural changes are also strongly affected by disturbance. Not only is the type of disturbance important (e.g., fire, logging, windthrow), but so is the intensity and timing of the disturbance. We often hear generalized statements, such as: "Disturbance, like windstorms, fire or clearcutting, causes pioneer species to take over the site." The three types of disturbance mentioned in this statement differ not only in the manner in which they affect the canopy, but also in how they affect many other factors, such as seedbed conditions, seed sources and response of competing vegetation. For example, low-severity disturbance (e.g., cutting during the winter with no disturbance of ground or advance regeneration) would favor shade-tolerant species. Medium severity disturbance (e.g., cutting in the summer with some soil scarification, or windthrow that creates tip up mounds) would likely lead to a mixture of shade-tolerant and mid-tolerant species. And finally, high-severity disturbance (e.g., hot fire that consumes organic matter on the forest floor as well as the canopy) would create an opportunity for invasion of intolerant pioneer species.

Any of the above factors may play a role in the dynamics of a given stand or vegetation community, making specific predictions of change difficult, if not impossible. However, forest managers must understand the effects of these factors as they apply in their region.

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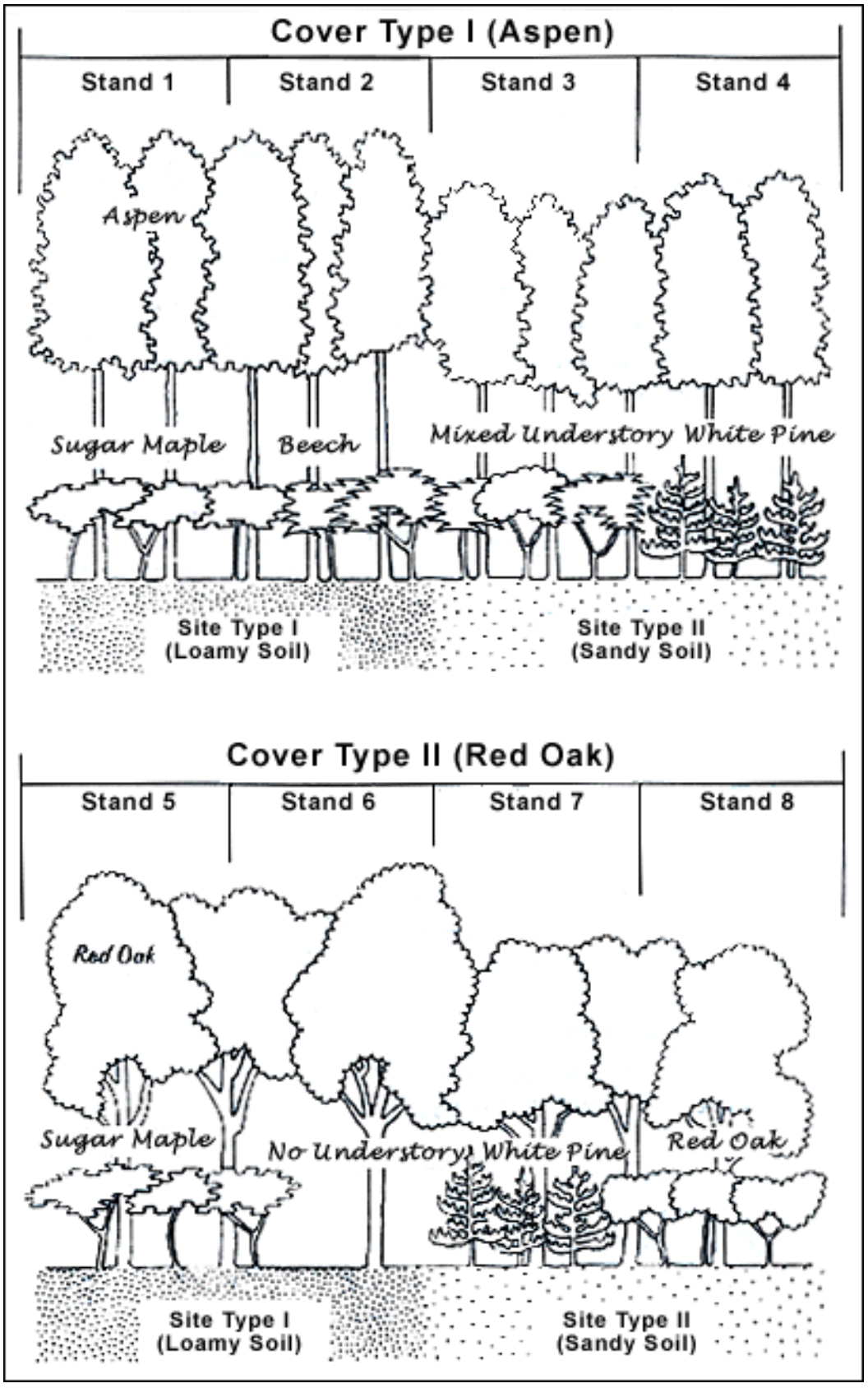
Forest Site

Forests are organized assemblages of trees, other plants and animals, in complex association with each other and their physical environment. Efforts to develop an understanding of the capability of land to produce timber have been an inherent element of forest management for more than a century. As emphasis in forest management changes from simply trying to grow the "best trees" on "the best sites" toward maintaining forests in a more natural condition while still utilizing the resources, it is becoming even more important that we pay attention to the physical environment that controls forest ecosystems.

So, what site factors are important and how do we evaluate them? The answer to this question varies from region to region. While perfect understanding of community-site relationships does not yet exist in any part of the world, enough useful information is available in most regions to enable forest managers to include site characteristics in their management considerations.

Figure 4 (page 10) illustrates the essence of site characteristics that affect tree growth, species composition and succession. All of these should play a role in the development of management recommendations. For simplification, the two site types in Figure 4 are labeled only as "loamy soil." However, the implications, are far reaching. Site Type I (loamy soil) has considerably higher nutrient content and moisture holding capacity than does Site Type II (sandy soil). As a consequence, Site Type I not only has a higher yield of current crop (aspen or red oak) than does Site Type II, but it also has a capacity to support two moisture- and nutrient-demanding species (sugar maple and beech) that Site Type Il does not. This has important successional implications for aspen and oak stands currently growing on both site types. Other site factors could easily be substituted for soil texture in Figure 4, e.g., north- vs. south-facing slope or valley bottom vs. ridge (other features in Figure 4 will be explained in subsequent chapters).

Figure 4. A schematic representation of two site types (loamy soil and sandy soil), two forest cover types (aspen and red oak), and eight stands. Each stand has unique composition and is defined by a specific combination of overstory and understory species. Each stand also can be considered as a unique ecological or silvicultural opportunity unit.


Cover Type I (Aspen)
Stand 1
Stand 2
Stand 3
Stand 4
Aspen
Sugar Maple
Beech
Mixed Understory White Pine
Site Type I
(Loamy Soil)
Site Type II
(Sandy Soil)
Cover Type II (Red Oak)
Stand 5
Stand 6
Stand 7
Stand 8
Red Oak
Sugar Maple
No Understory
White Pine
Red Oak
Site Type I
(Loamy Soil)
Site Type II
(Sandy Soil)

In practice, any site factor that is expected to produce similar differences as illustrated above could be considered as a basis for site type differentiation. In some regions, various site classification systems have been developed and serve as valuable tools in forest management. For example, in Wisconsin and Michigan, forest sites have been classified along a soil moisture-nutrient gradient (Kotar and Burger, 1996, A Guide to Forest Communities and Habitat Types of Central and Southern Wisconsin; Kotar, Kovach and Locey, 1988, Field Guide to Forest Habitat Types of Northern Wisconsin; Coffman, Alyanak, Kotar and Ferris, 1980, Field Guide to Habitat Type Classification System for Upper Peninsula of Michigan).

Segments of the gradient are referred to as "vegetative habitat types." In the field, individual habitat types are recognized by the presence of characteristic understory species. Keys to diagnostic plants and community descriptions are used to classify a given site. In addition, potential forest dynamics (successional pathways) and management implications are presented for each habitat type.

In some regions, especially on eastern National Forests, a system of hierarchical land units is being developed (e.g., Cleland et al. 1992. Field Guide - Ecological Classification and Inventory System of the Huron-Manistee National Forests). In this system, the smallest units, called ecological land types (ELTs), function similarly to site types described in Figure 4. When information on the productivity of individual tree species and on potential community dynamics is available for ELTs, they can be used in a similar way as the habitat types.

Where no formal site and community classifications exist, forest resource managers may have to consult available local sources on geology, soils and vegetation ecology in order to differentiate ecologically significant site types on lands they manage.

The following is a list of generally recognized factors that directly affect site quality, primarily in terms of available soil moisture and nutrients and, in some cases, also temperature and light:

Relatively favorable sites	**vs.**	**Relatively unfavorable sites**
Broad ridges	vs.	Narrow ridges
Lower slopes	vs.	Upper slopes
Gentle slopes	vs.	Steep slopes
N and E aspect	vs.	S and W aspect
Deep soil	vs.	Shallow soil
Fine-textured soil	vs.	Coarse-textured soil
Good drainage	vs.	Poor or excessive drainage

It is important to recognize, however, that numerous combinations of the above factors (from left and right columns) can result in functionally similar sites. This makes site quality evaluation more difficult in the absence of regional studies. For example, without additional information, it is difficult to estimate which of the paired site factors below results in more favorable moisture and nutrient conditions:

Lower/slop/shallow soil	vs.	Upper slope/deep soil
N aspect/upper slope	vs.	S aspect/lower slope
N aspect/coarse soil	vs.	S aspect/fine -textured soil
Deep, coarse soil	vs.	Shallow, fine-textured soil
N aspect/deep, coarse soil	vs.	S aspect/deep, fine -textured soil

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Stand or Vegetation Unit

A stand may loosely be defined as a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes and general condition so as to be considered a homogeneous and distinguishable unit. For management that includes a variety of goals and purposes, it is sometimes necessary to use a more general term since "stand" normally refers to a community of trees. "Vegetation unit" can be used whether we are referring to a forest or any other vegetation such as shrub thicket, meadow or prairie. However, because of its well established use, the term "stand" will be used here when referring to forest vegetation.

One of the most serious obstacles to intensive forest management and particularly "ecologically based" management is the practice of defining stands too broadly. If a stand is delineated chiefly by a loosely defined composition (cover type), it may encompass more than one site type, as' well as a range of advance reproduction and other regeneration opportunities and limitations. If a stand is to be used as a basic unit of manipulation, it should represent a uniform "ecological opportunity unit."

This concept is illustrated in Figure 4, which shows two site types (loamy soil and sandy soil) and two forest cover types (aspen and red oak). The two cover types are each divided into four stands based on differences in understory composition (i.e., advance regeneration).

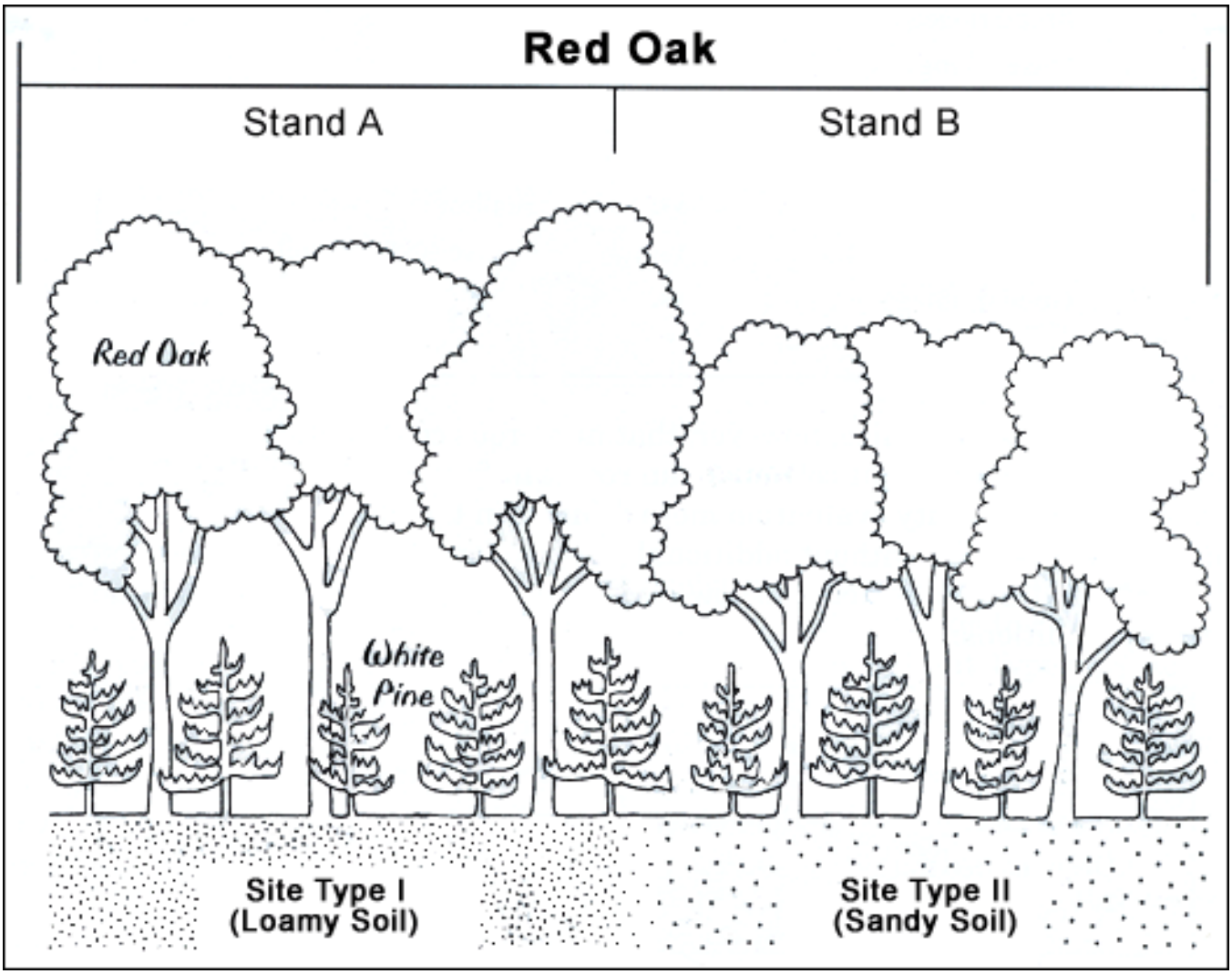

Figure 5. A single stand (red oak overstory with white pine regeneration) "straddles" two

significantly different site types. Because ecological and silvicultural potentials differ for the two site types, the stand was split (A and B) to identify two ecological and silvicultural opportunity units.

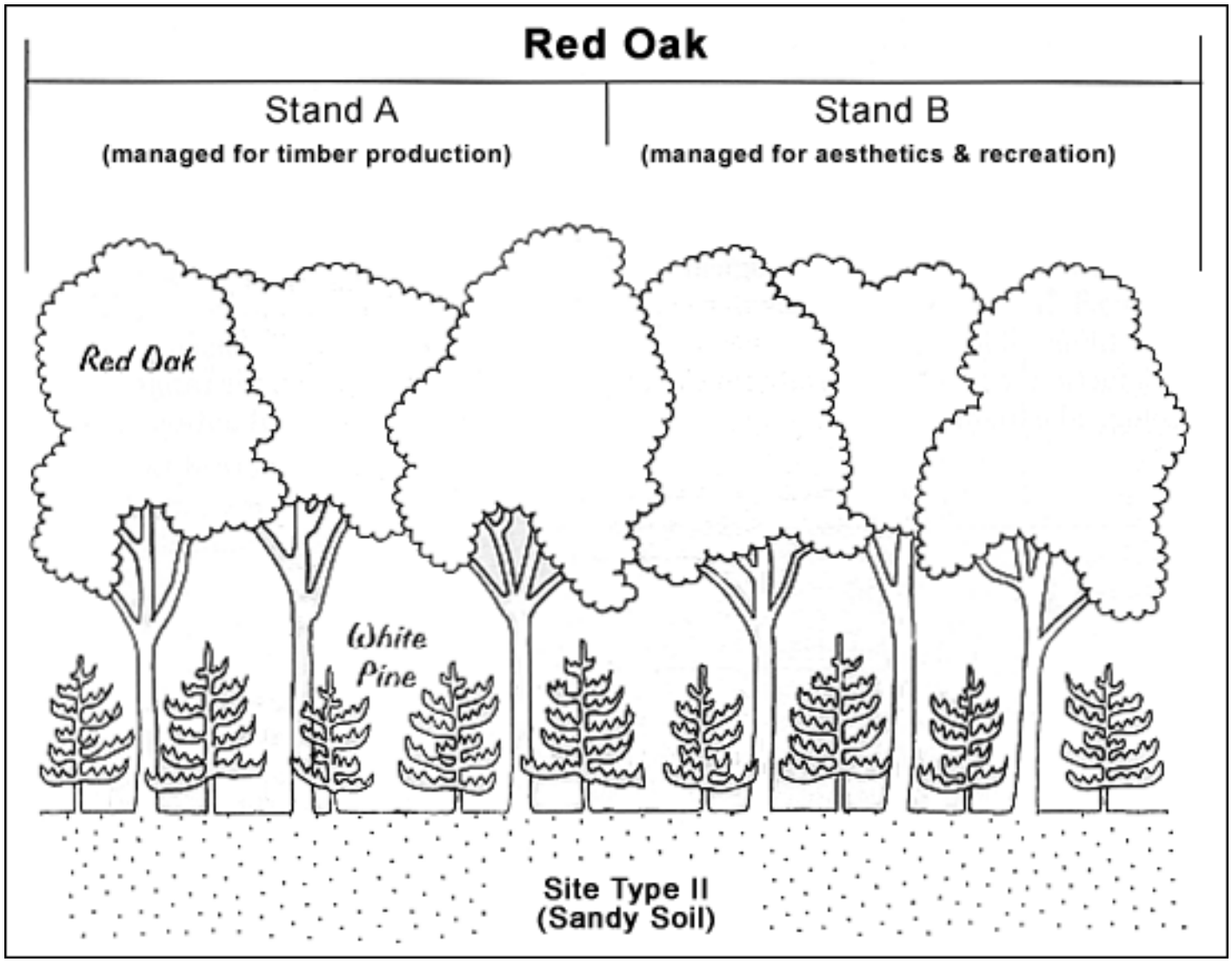

Figure 6. This stand is divided into two management units on the basis of different management objectives. E.g., in stand A, oak will be harvested and white pine released to form a new crop, while in stand B, oak overstory will be retained to provide a food source for wildlife and conditions for future old growth."

If the aspen cover type regenerated on both site types after the same fire, a forester unaware of site type differences could have grouped stands 1-4 into one large stand. If site differences were recognized (e.g., by differences in tree height and density or soil texture), but advance regeneration was ignored, only two stands would have been recognized, one on each site type. Only when regeneration was duly noted were four ecological opportunities recognized and four stands delineated. A similar scenario is depicted for a red oak cover type in Figure 4 (stands 5-8). Consideration of this many stands may be practical only if they were large enough to make individual treatment prescriptions economical. Thus, the actual minimum size of stands will vary with ownership.

Many tree species have wide ecological amplitudes (i.e., grow on a wide range of sites). Cover types comprised of such species are often lumped into large, single stands even if they cross significantly different site types. Under such conditions, important management opportunities may be lost. Figure 5 (page 12) illustrates such a case.

There is one situation in which a stand representing a uniform ecological opportunity unit may not be considered as a basic treatment unit. If the owner chooses different management objectives for different parts of a uniform stand, then each objective defines a separate "management unit" and new stands should be delineated (Figure 6). These stands will become more different from each other as different prescriptions are applied.

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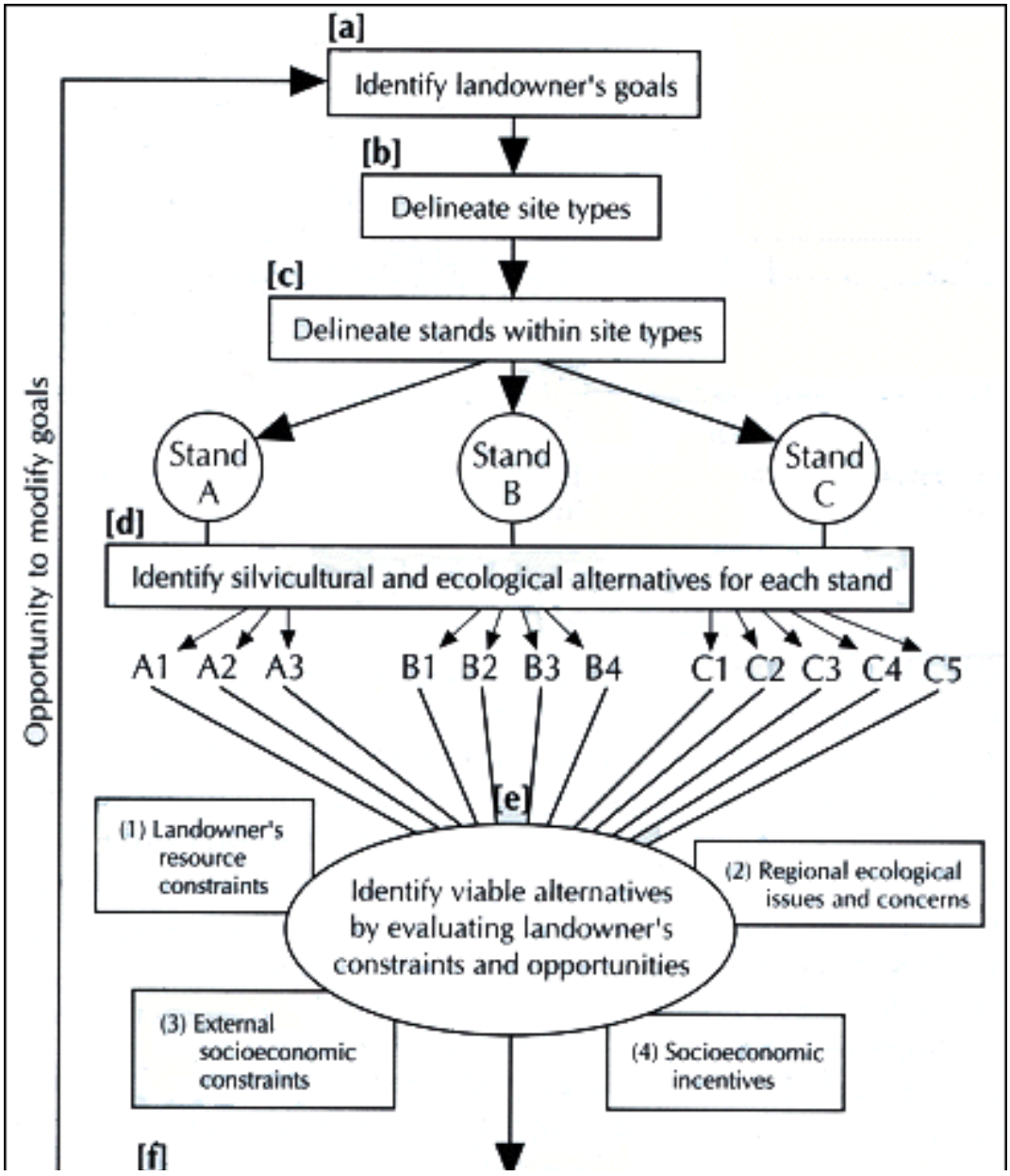
PART II: Suggested process for developing an ecologically based forest management plan

Forest management - or stewardship - plans can be approached in many ways. A well thought-out ecological approach involving the landowner is most likely to lead to that landowner's satisfaction, as well as maintenance of ecological capability of the land.

The essence of following an ecologically based approach to forest management is an understanding of forest community dynamics as a function of site and disturbance, and identifying a much wider range of acceptable silvicultural options than is traditionally recognized in commodity oriented forest management, when just current cover types are considered.

A suggested process to develop management options is depicted in Figure 7. It should be emphasized that this is a **process** (i.e., a sequence of steps to consider), and not an outline of items to be specifically included in actual management plans.



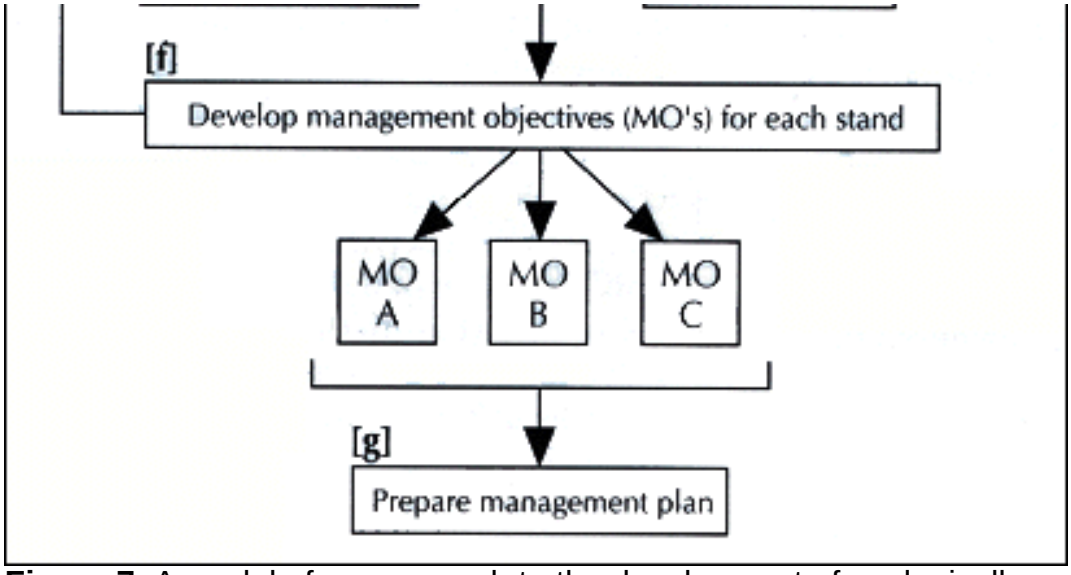


Figure 7. A model of an approach to the development of ecologically sound forest management plans.

Explanation of process components in Figure 7:
Major steps are designated by letters (a,b,c) beginning at the top of the diagram.

[a] Identify landowner's goals.

Forest resource professionals must communicate with the landowner to identify his/her long-term goals for ownership and management of forest land. Communication skills, particularly the ability to listen, are required. Sample goals may be: to create habitat for a wide range of wildlife species; to maximize income from wood production; or to provide the best possible deer habitat.

[b] Delineate site types.

Land within an ownership can be relatively homogeneous or heterogeneous in terms of its ecological capability. Major factors affecting species' ability to grow, reproduce and compete include soil depth, texture and chemical properties, and position on the landscape (such as north or south slope aspect, ridge or valley, etc.). Any areas within the ownership that can be differentiated on the basis of such factors should be identified as "site types." In some areas, formal site classification systems have been developed.

[c] Delineate stands within site types

. Because stands - vegetation units represent communities of different composition and structure, and therefore different stages of development cycles, they must be considered separately if management based on ecological principles is to be attempted. Each stand is considered to be an "ecological opportunity unit."

[d] Identify silvicultural and ecological alternatives for each stand.

Short- to mid-term compositional and structural changes in most vegetation units are relatively predictable. However, current development trends are not necessarily the only ecologically acceptable pathways, and they may not meet the owner's goals. Before deciding on the most visible management option, a resource professional should first attempt to identify other ecological alternatives (A1-C5 in Figure 7). These will be considered later in the development of management objectives. Each stand, if properly delineated, can be expected to respond uniformly to a given natural disturbance or management action. Although there are definite limitations due to site, stand composition, and availability of external seed sources, there is almost always more than one ecologically sound silvicultural alternative available. **All too often, regenerating the existing cover type is the only option considered.** Such a choice may not always be ecologically desirable nor may it best meet the landowner's goals. More management options can be offered to the landowner if all ecologically feasible alternatives are first identified.

Systematically identify ecological and silvicultural alternatives by evaluating the following factors:

- *Successional role of each species comprising the current stand (overstory and understory).*
  This information is essential for planning changes in stand composition and regeneration techniques.
- *The age structure of the stand*
  Species composition and age structure are the two fundamental properties of any forest stand. They must be taken into account in any management consideration..
- *Relative growth potential of each species on identified site type.*
  This may be the most important information for any management decision because growth potential relates not only to economic outputs, but also strongly affects forest dynamics.
- *Presence of advance reproduction.*
  Presence or absence of advance reproduction to a large extent dictates the type of regeneration techniques that will be applied. Also, advance reproduction may or may not be the desired species.
- *Expected reaction of advance reproduction to different types of stand manipulation.*
  If advance reproduction is of mixed species, different growth rates can be expected with different degrees of canopy removal. Seedlings of most species benefit from complete canopy removal, but some shade-tolerant species respond best to gradual canopy removal.
- *Expected effect of competing vegetation after opening of the canopy.*
  Understory plant species respond differentially to removal of the forest canopy and present different degrees of competition to tree seedlings. Response of competing vegetation also varies among site types. Generally, the more mesic the site, the stronger the understory competition. However, potential competing species are not necessarily present in every stand.
- *Potential for inducing advance reproduction of each canopy species.*
  Regeneration requirements vary greatly with species. Some conditions are more difficult to meet artificially than others.

- *Potential for introducing other tree species suited for the site type that are not present in the current stand.*
  Current stand composition is invariably the result of past treatments or disturbances and does not necessarily include seed sources of the best adapted or most desirable species. Reintroduction of such species is often possible by planting or direct seeding.

- *Existing and potential damaging agents.*
  Some species are more susceptible to specific damaging agents (e.g., insects, pathogens, frost, windthrow) in certain regions or on certain site types.

[e] Identify viable alternatives by evaluating landowner's constraints and opportunities.

(1) *Landowner's resource constraints.*
Some silvicultural and ecological opportunities identified above may not meet an owner's financial expectations or may exceed his/her commitment of time.

(2) *Regional ecological issues and concerns*.
Management practices that are ecologically sound on a site or local ecosystem level may not address landscape and regional concerns. Although private owners are not obligated to consider regional ecological concerns (other than those specifically covered by law, e.g., the Endangered Species Act), many of them are interested, and often eager, to accommodate them within limits of economic efficiency. Resource professionals working with private owners should be aware of such issues and bring them to the owner's attention when preparing management plans. Such issues vary greatly from region to region and cannot be addressed comprehensively. The following are some examples:

- Lack of large contiguous blocks of specific habitats to accommodate wide-ranging animal species or those that do not thrive in edge habitats.

- Need for special wooded corridors to accommodate movement of some animal species between suitable habitat patches.

- Loss of certain vegetation types (and accompanying fauna) due to changes in natural disturbance regimes (e.g., loss of oak savannas or pine forests due to suppression of wild fires).

- Shortage of mature stages of forest development due to uniformly applied economic rotation age.

- Reduced compositional and structural diversity of forest communities due to prevailing management practices.

- Lack of tree regeneration, and reduction of shrub/herb density and diversity due to high deer densities.

(3) *External socioeconomic constraints*
Certain activities may be constrained by zoning laws or forest practice regulations, while others may simply conflict with prevailing attitudes of neighbors or the general public. While the owner is not bound by the latter, a conscientious resource professional will keep landowners informed in order to minimize potential future conflicts.

(4) *Socioeconomic incentives.*
Socioeconomic constraints often can be balanced by incentives. These may include lower property taxes on managed forest land, income tax deductions for forest management investments, government cost-sharing for management practices and others. Some practices also may engender greater public acceptance than others without compromising an owner's goals.

[f] Develop management objectives (MO's) for each stand.
The steps described above identify ecologically sound silvicultural alternatives for individual stands and eliminate from consideration those that cannot be supported on socioeconomic terms. The landowner now must select the management objectives for each stand.

[g] Prepare management plan.
Only when management objectives have been defined through this type of process should the management plan (i.e., 'action plan") be developed. The management plan is a written document that summarizes all of the above information and then clearly prescribes management unit activities and a timeline for accomplishing them. Detailed silvicultural prescriptions are not part of the initial management plan; these are developed immediately prior to a scheduled management practice in order to take into account unique stand conditions.

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Summary

Traditional forest management is often limited to maintenance or perpetuation of existing forest cover types. This approach does not always meet landowners' or society's best interests. Landowners and society are better served if forest resource professionals understand ecological characteristics of individual species and forest dynamics in the context of site quality. This understanding enables resource managers to identify a wider range of alternatives for meeting landowners' goals. Management based on ecological principles is also more likely to assure forest sustainability.

Glossary

Ecological (or silvicultural) opportunity unit

A combination of specific site type and specific forest stand (or some other definable vegetation unit). Two different kinds of stands on the same site type represent two different ecological/silvicultural opportunity units. Conversely, a single stand straddling two site types can be split into two ecological/ silvicultural units. Each ecological opportunity unit offers certain management possibilities and is subject to certain limitations, due to combined factors of site quality and stand characteristics.

Forest cover type

A broad classification of a forest based entirely on current dominant tree species (e.g. aspen, aspen-birch, maplebasswood, oak-hickory). Cover types are consequences of disturbance history ("natural" or human-caused) and site quality. They change with time and should not be presumed to be "natural" or stable vegetation communities.

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Forest stand

A stand may loosely be defined as a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes and general condition so as to be considered a homogeneous and distinguishable unit. A stand is usually treated as a basic silvicultural unit, but it seldom represents a natural ecological unit. Its composition and structure are most strongly affected by management, other disturbances and chance factors affecting seed distribution, germination and seedling survival.

Management goal

Overall purpose for controlling (managing) the composition and structure of forest land. For example, to protect land from erosion; to maintain wildlife habitat; to grow wood for profit.

Management objectives

Defined conditions for the property or segments of property (e.g., stands or management units) that will achieve management goals. For example, maintenance of continuous forest cover may be the only objective if watershed protection is the primary goal. A mixture of deciduous and coniferous cover may be the objective for enhancing the variety of wildlife. Another objective may be to grow tree species with highest yields in order to maximize financial returns from wood production.

Management plan

A plan outlining the objectives for individual management units and describing steps for achieving them. Silvicultural procedures are identified in broad terms, but detailed prescriptions are developed in the field.

Management unit

Management objectives define management units. Stands can be managed to achieve different goals. If one or several compatible management objectives are to be pursued on a stand, then the entire stand can be considered as one management unit. If, on the other hand, two or more incompatible management objectives are selected for the same stand, the stand should be divided into separate management units based on compatible objectives.

Mesic

A relative term applying to moisture conditions on a site. A midpoint on a gradient from dry to wet. Considered to be favorable to the largest number of species in a particular region.

Silvicultural prescriptions

Specific steps prescribed to achieve specific management objectives. Examples: If the management objective is to maintain an oak component in a mixed stand, the silvicultural prescription may include opening up the forest canopy to initiate the establishment of seedlings of shade-intolerant oaks. If undesirable species are dominating the canopy and a desirable species is becoming established in the understory, the silvicultural prescription may be to remove overstory trees to release the suppressed desirable species. Thinning and planting are other examples.

Site potential

Collective physical resources (e.g., soil moisture, nutrients, light, heat) available for plant growth. Different potentials facilitate growth of some species and limit growth of others. Consequently, site potential has a strong effect on plant community development.

Site type

A portion of land characterized by specific physical properties that affect ecosystem functions and differ from other portions of land. Examples are differences in soil depth, texture or other important properties; slope aspect (e.g., north vs. south); position on the slope (e.g., upper vs. lower); or steepness. In some regions, formal site classifications have been developed, but in most instances site type differentiation and interpretation will have to be developed by individual resource professionals from available literature, maps and direct observation.

Stand composition

The mixture of tree species.

Stand structure

The complexity or arrangement of tree age/size classes.

Tolerance (shade tolerance)

A plant's ability to tolerate conditions under a forest canopy. Normally thought of as tolerance to low light conditions, but other understory conditions, such as root competition for water and nutrients, are also factors.

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